Initial Calibration for the CMS Hadronic Calorimeter Barrel

Mayda M. Velasco

Northwestern University

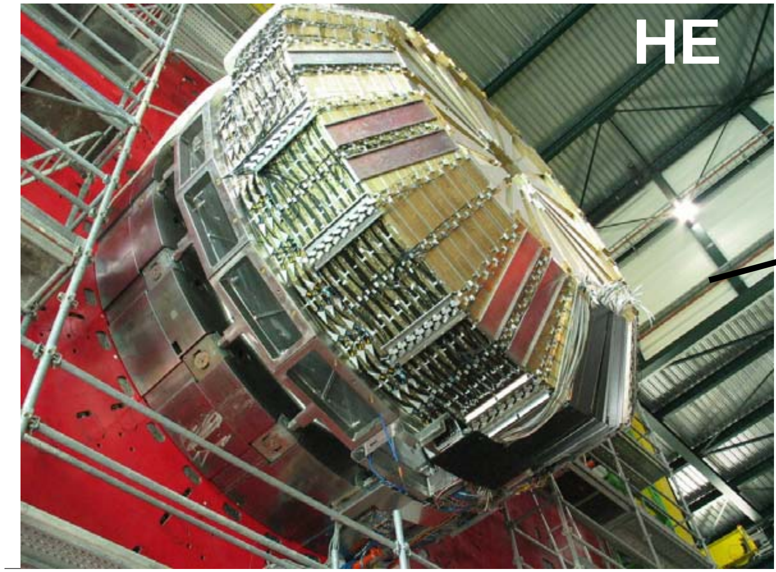
June 8, 2006

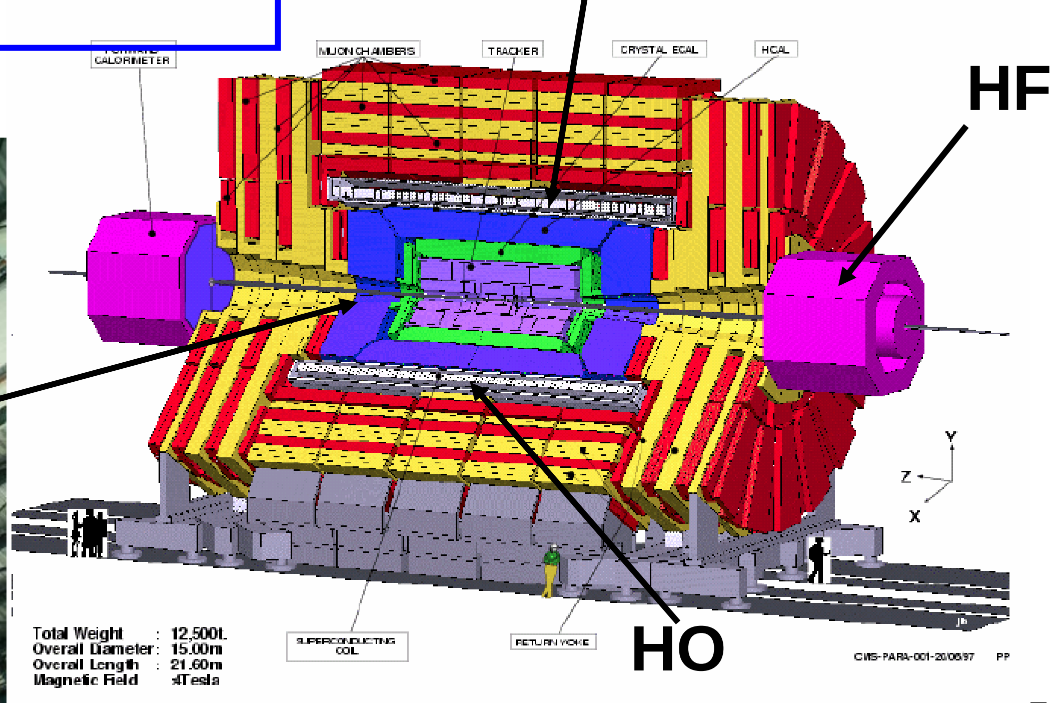
CMS Hadron Calorimeter

➔HB/HE = Barrel/Endcap Sampling Calor. Brass + Scint.
-- Same Calibration Techniques

➔HO = Outer Calor. Layer(s) of scint. outside of solenoid

➔HF = Forward Calor. Iron + quart fiber





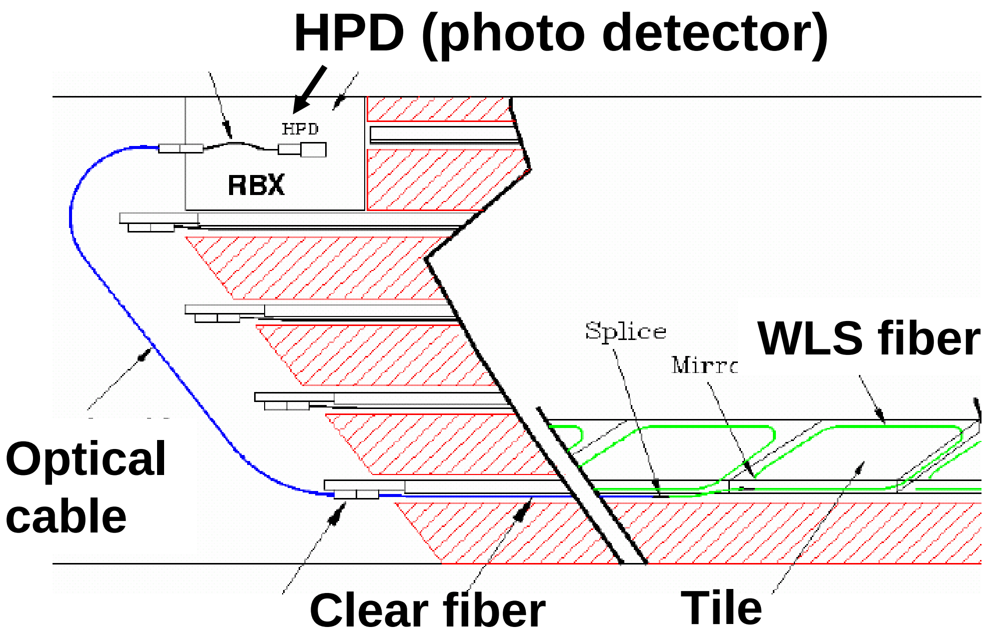
1st Input to Calibration

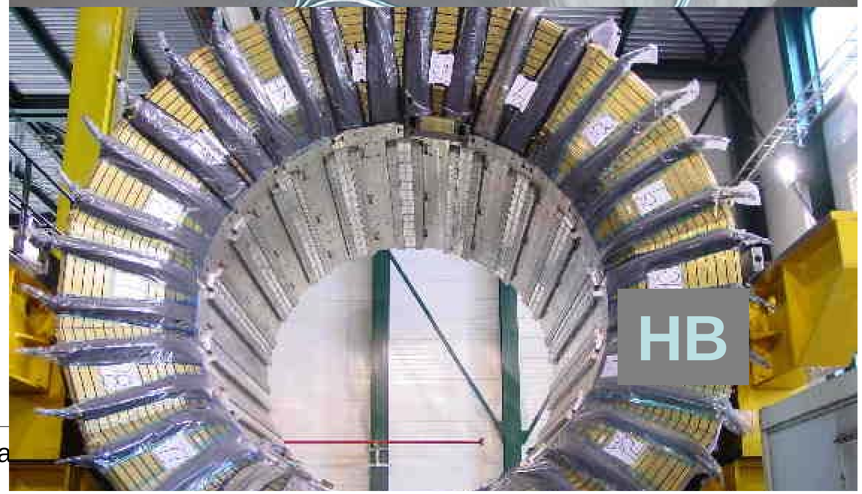
Quantify:

➔ Scintillator/tile quality

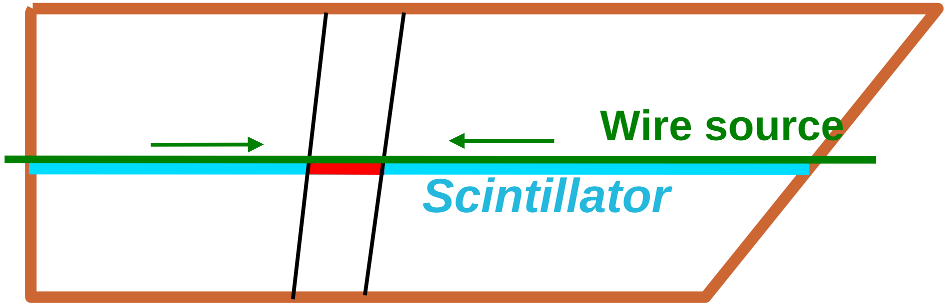
➔ Fiber transport & attenuation

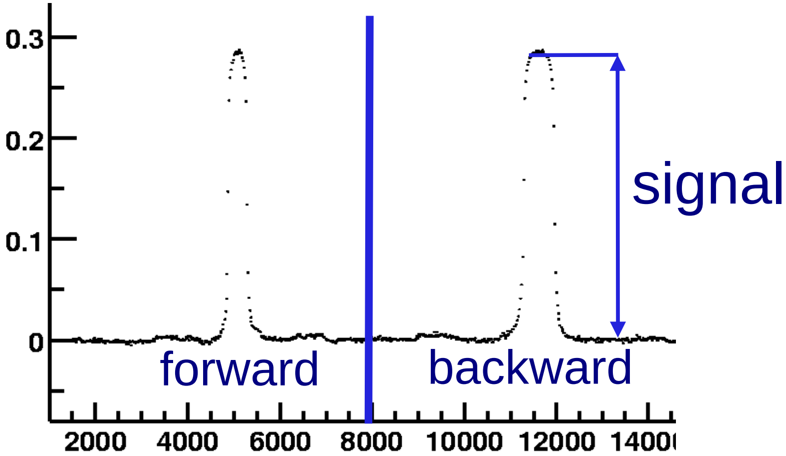
➔ Gain of photo detector





1st Step: “sourcing” In-situ for all tiles ➔ Finished





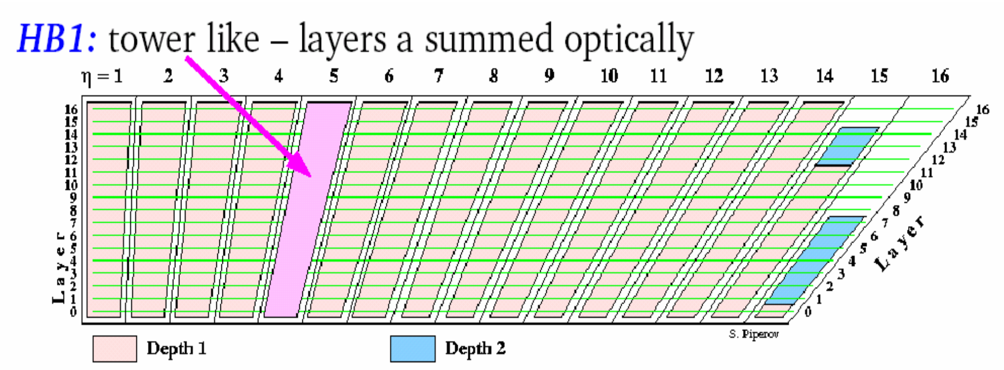
The uniformity calibration is done with Co^{60}, per-tower and per-layer with precision about 2%.

- **Sourcing provides the 1st information on detector uniformity**

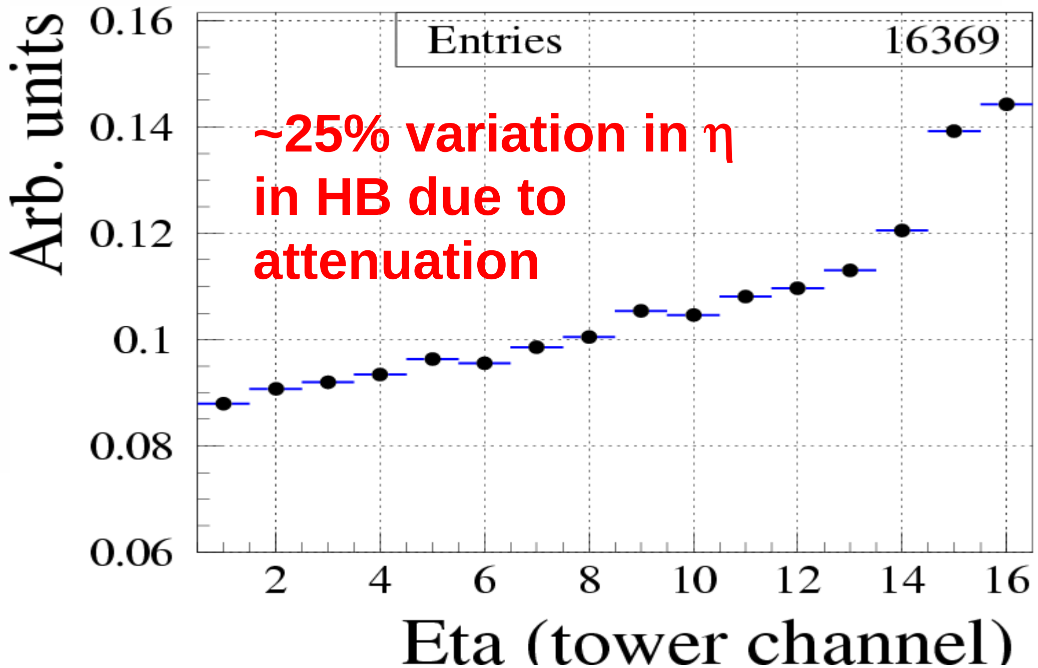
- **Source➔SciTile in a layer**
  to fiber
  to photo detector

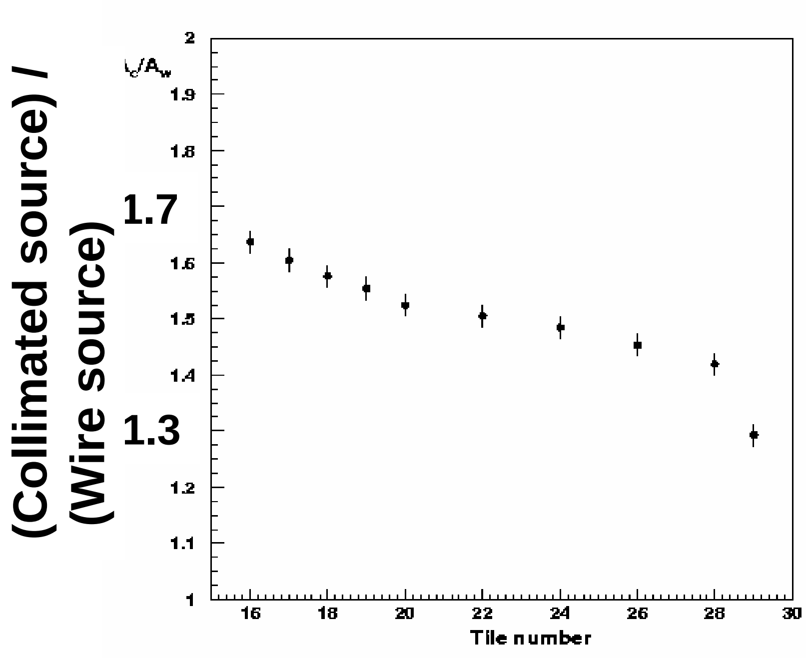
- **Found ➔ Layer-to-Layer variation to be < than 10% as requested by design**

Variation as function of η in in HB as expected due to signal attenuation

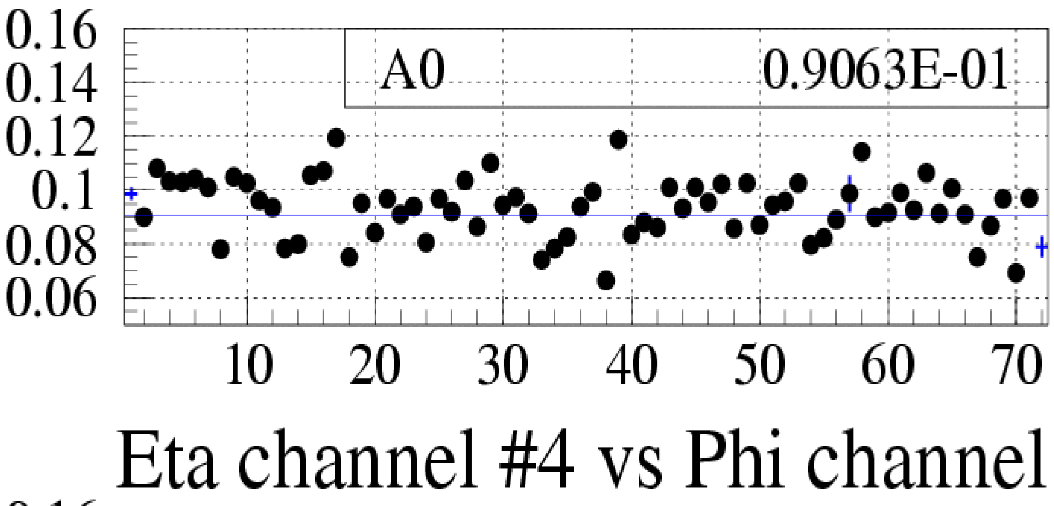


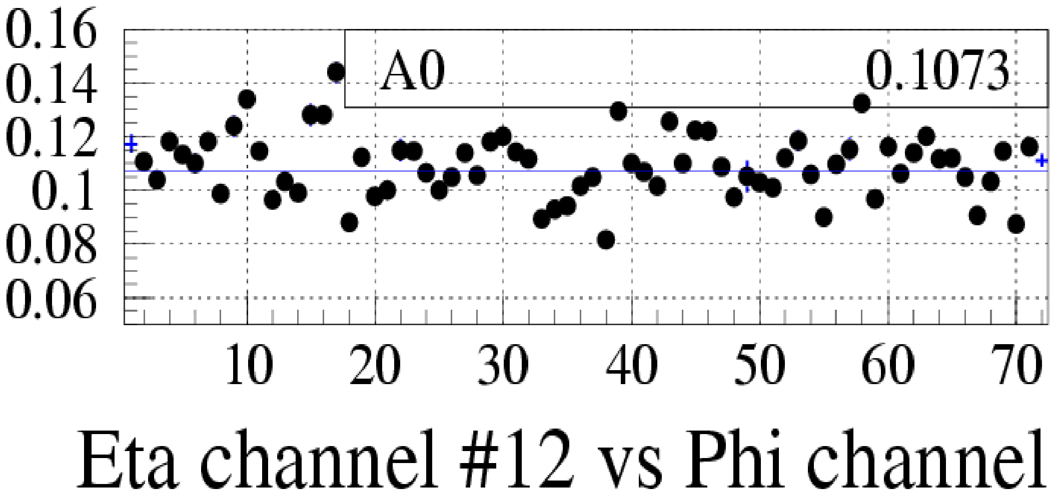
Similar for HE just need to take into account source effects due to small tiles compared to source illumination



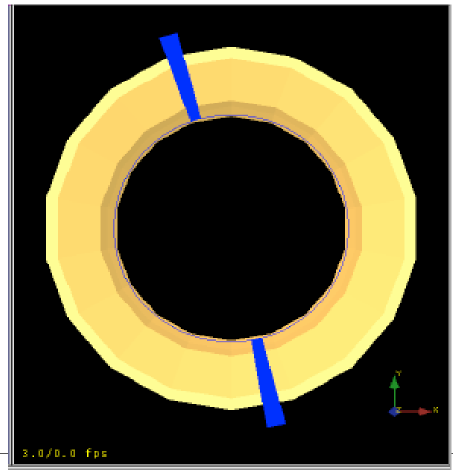


Differences in Gain versus ϕ for HB+





- ➔ **5% spread – maximum phi-to-phi deviations reflects mostly difference in gain of the photo detectors**
- ➔ **Gain ~ 2000 at chosen operating voltage**
- ➔ **<2% measurement made for each channel**
- ➔ **Can be confirmed with cosmics**

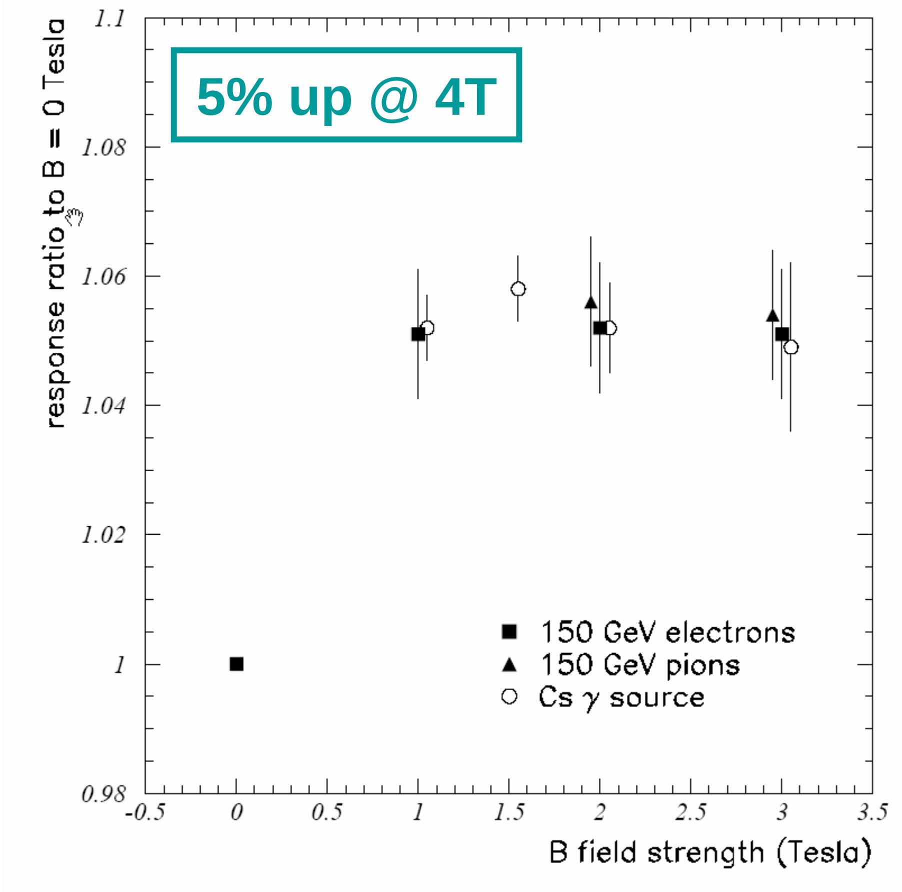


Cosmic data from a few months ago

2-3 GeV

Source results need to be corrected for B-field effects

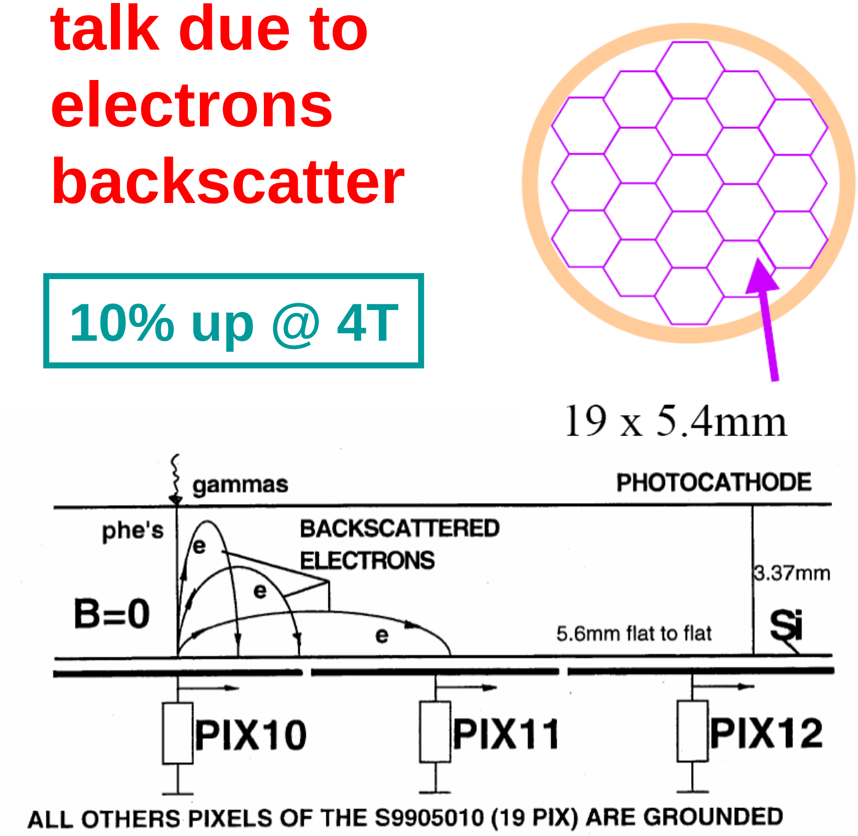
#1 Scintillator brightening



More light output in B-field

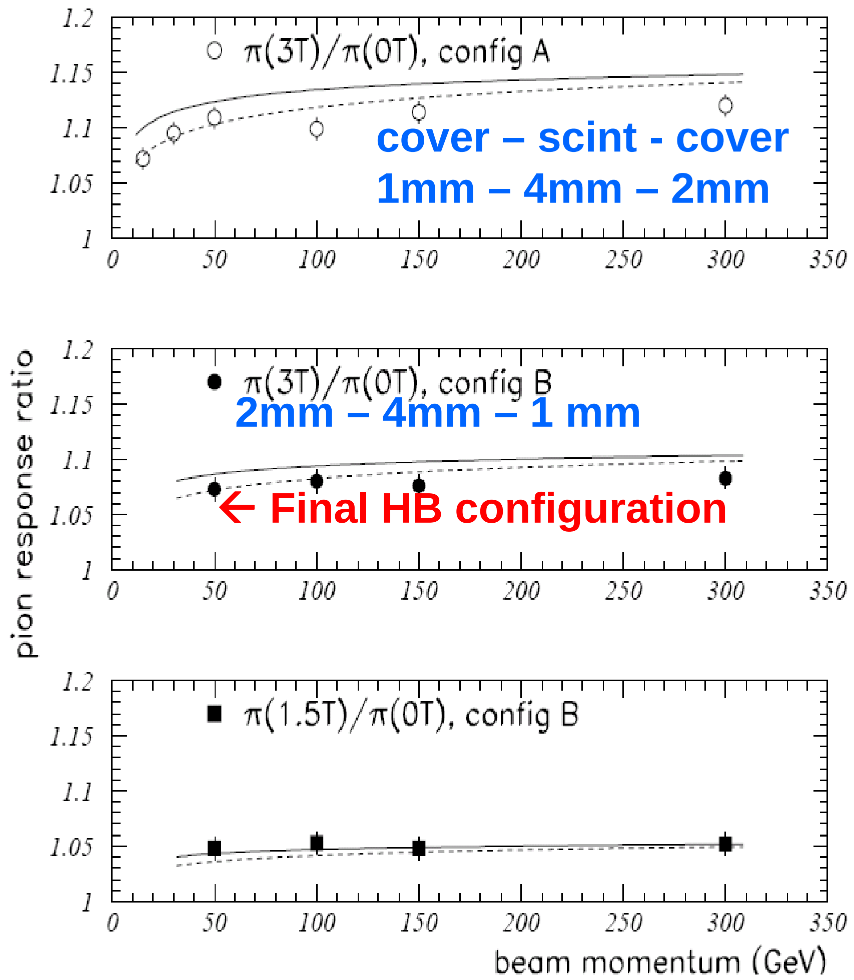
#2 HPD pixel cross talk due to electrons backscatter

10% up @ 4T



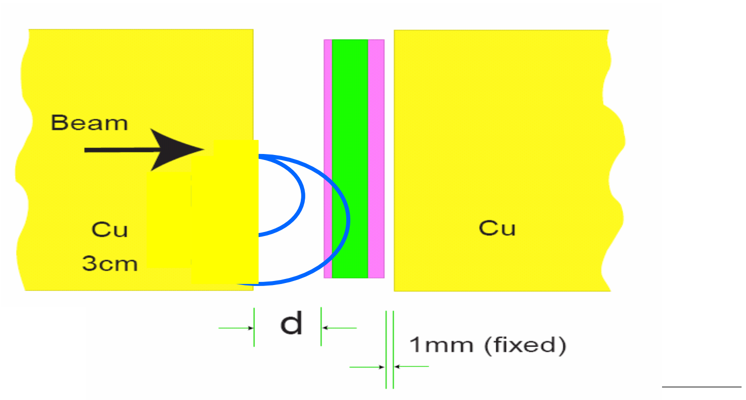
No cross talk in B-field
e- trapped along B-field line.

Continue…Source results need to be corrected for B-field effects



- Design parameters optimized to minimize **path length effects** in the presence of magnetic fields

- **#3 Small 1-2%** energy lost MC estimates



Path length effect Only Important for HB

HE configuration

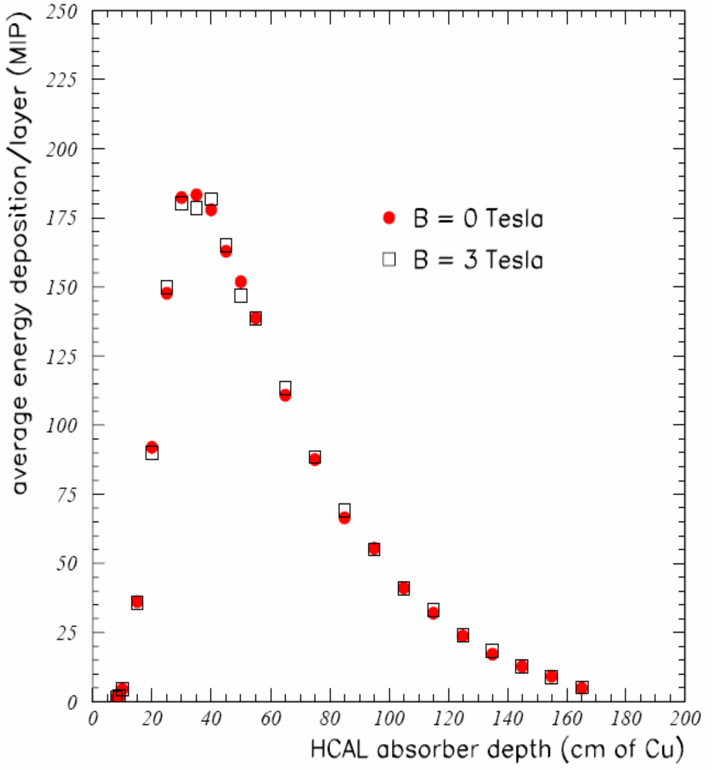


Figure 9: H2(1995) data: comparison of 300 GeV/c pion shower profiles for B=0 and B=3 Tesla magnetic fields. The B field lines are perpendicular to the scintillator plates (endcap configuration). The pion shower profiles are divided by the average muon response for each layer, which corrects for the overall scintillator brightening effect.

HB configuration

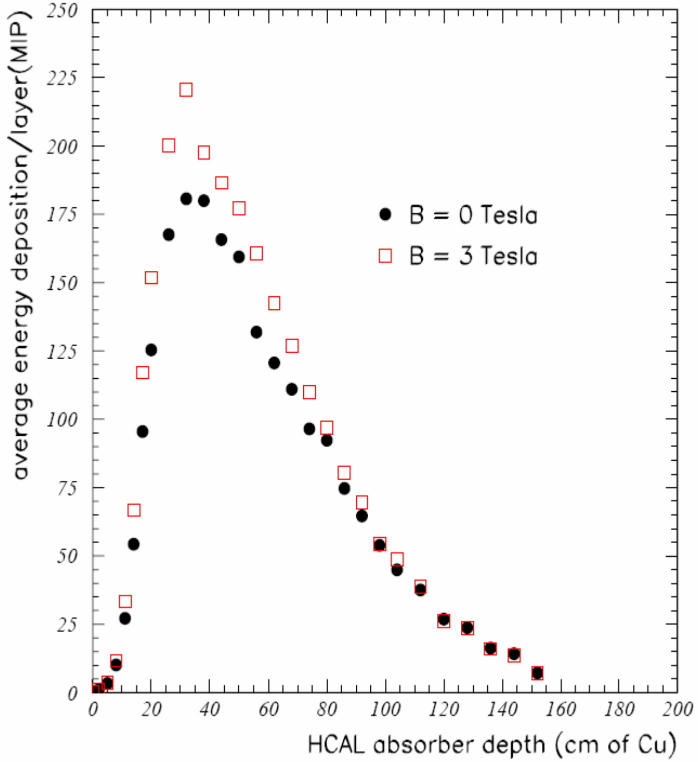


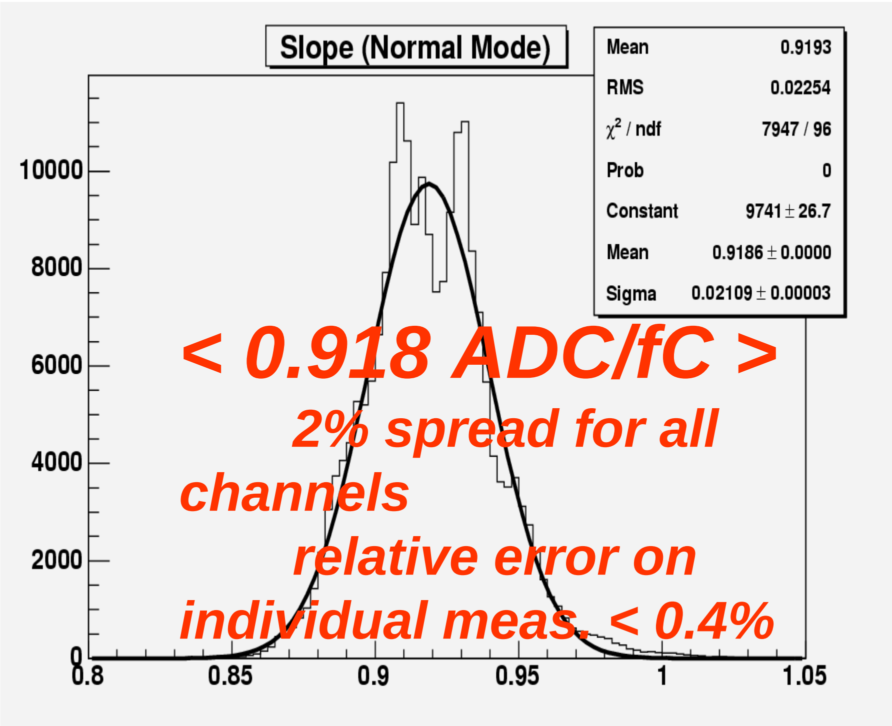
Figure 10: H2(1996) data: comparison of 300 GeV/c pion shower profiles for B=0 and B=3 Tesla magnetic field. Here, the B field lines are parallel to the scintillator plates (barrel configuration). The pion shower profiles are divided by the average muon response for each layer, which corrects for the overall scintillator brightening effect.

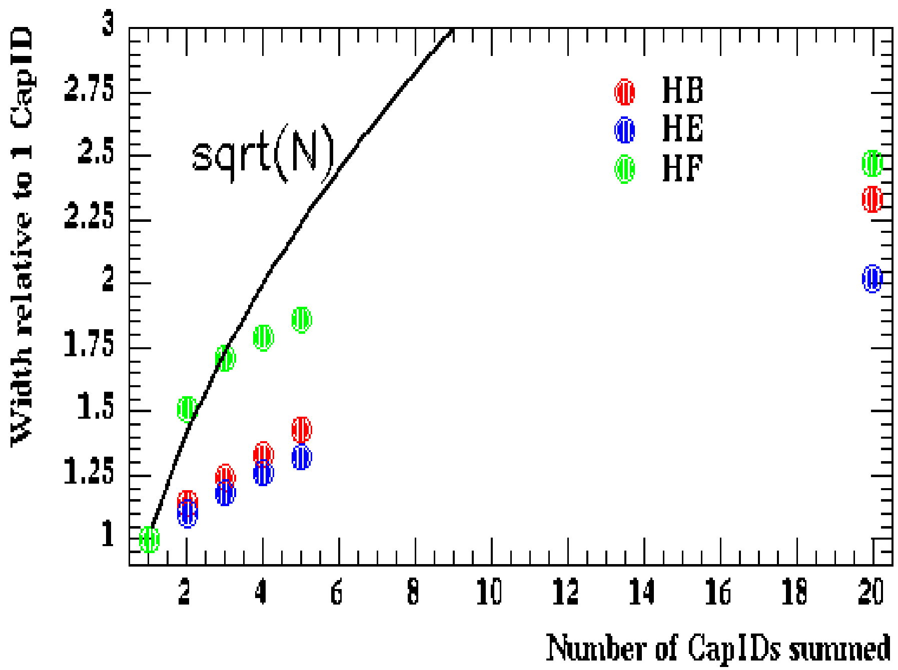
2^{nd} Input to Calibration

- **ADC calibration with charge injector (ADC → fC)** *(Whitmore)*
- **Pedestal Subtraction**
- **Time Syncronization**

- **Ped. Noise for single Time Slice = one capacitor 0.7 fC (~180 MeV)**
- **Pedestals Stable BUT correlated for consecutive time slices (25ns = 1 bucket)**

- ***Why do we care?***

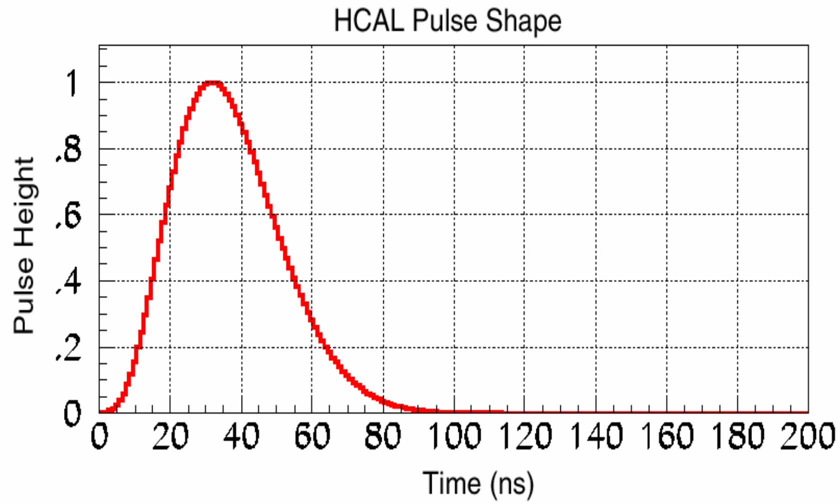


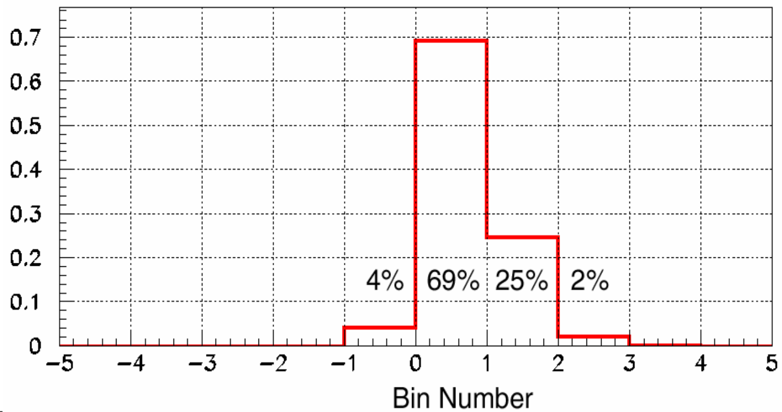


Time Slice (25ns)

Ped. Subtraction in 2TS & time Synchronization needed due to time spread of HCAL Pulses

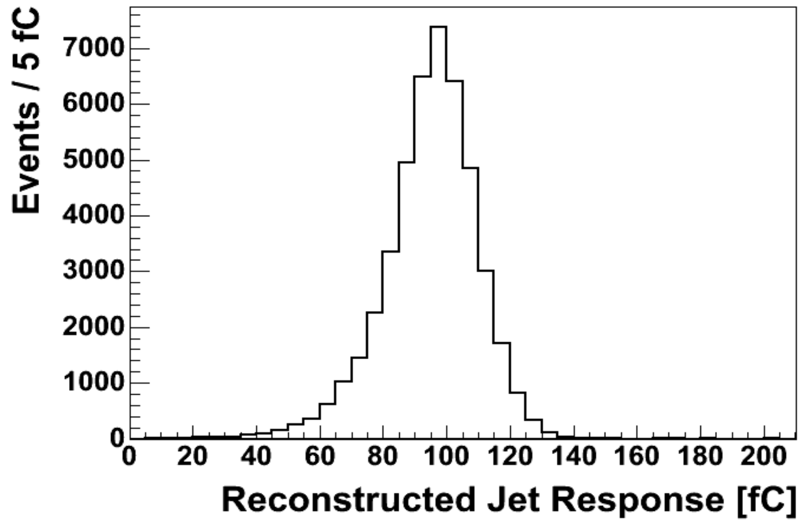
- **Nominal HCAL pulse spread over several 25ns buckets**
  - **Fraction in bucket is tunable via clock phase adjustment**
  - **~90% signal collected in 2TS=50ns**
- **Need to recover "event" concept, associate energy to a single crossing (bucket) and report it to the trigger**

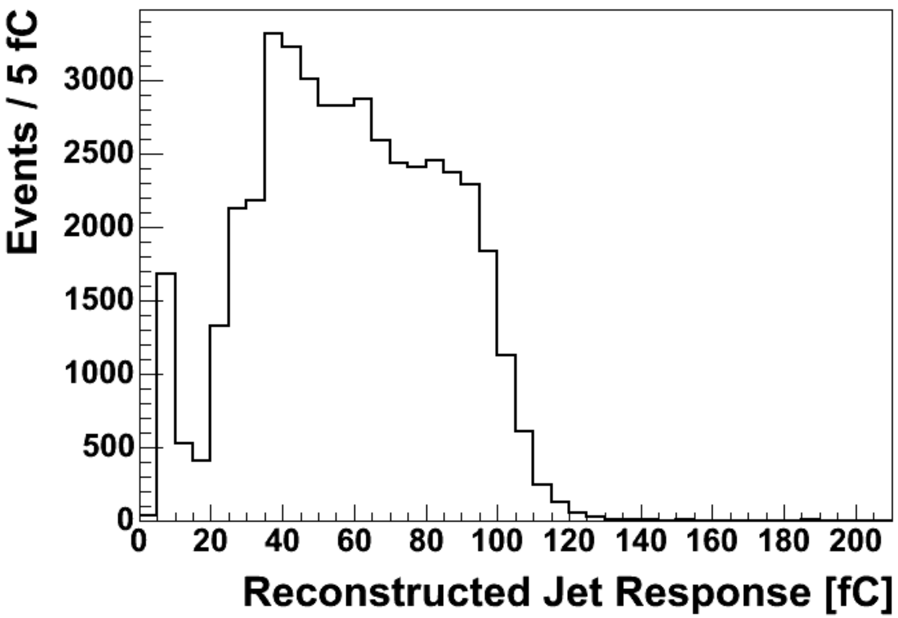




Timing errors will be disastrous…at the trigger level

300 GeV pions when properly timed in

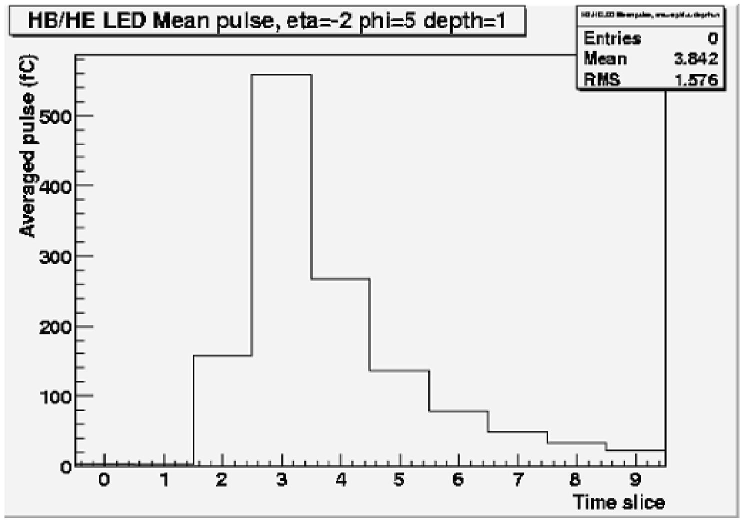


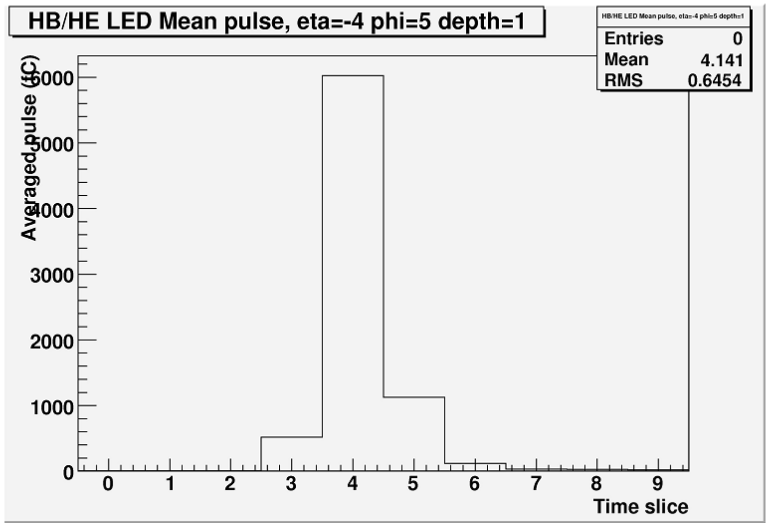


300 GeV pions when late by one bucket (same events)

Synchronization is important!

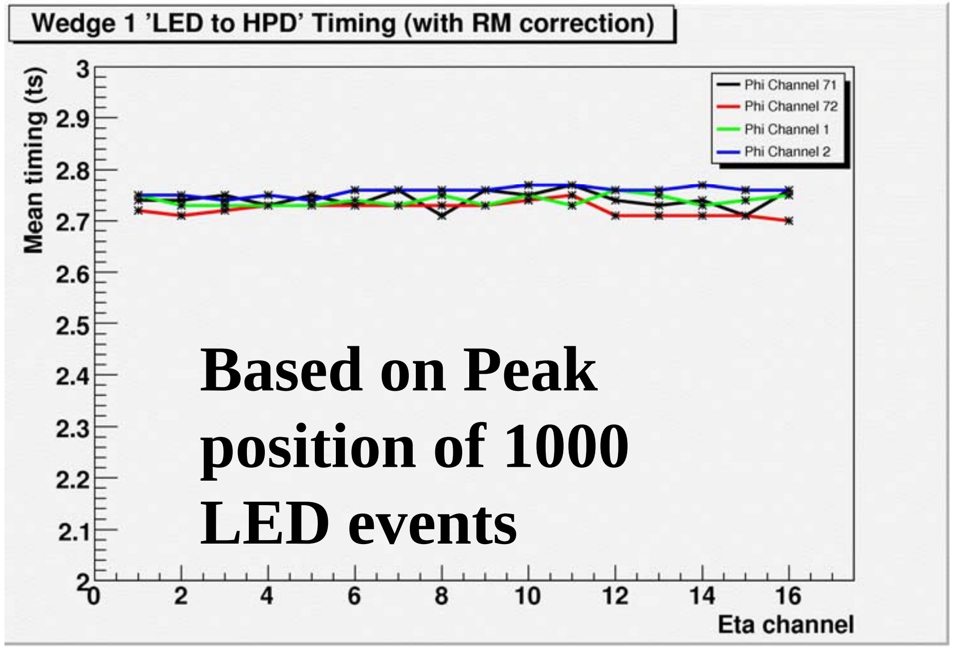
Accuracy required 0.1 time-slices → 2.5ns can be achieved from LED or Laser system

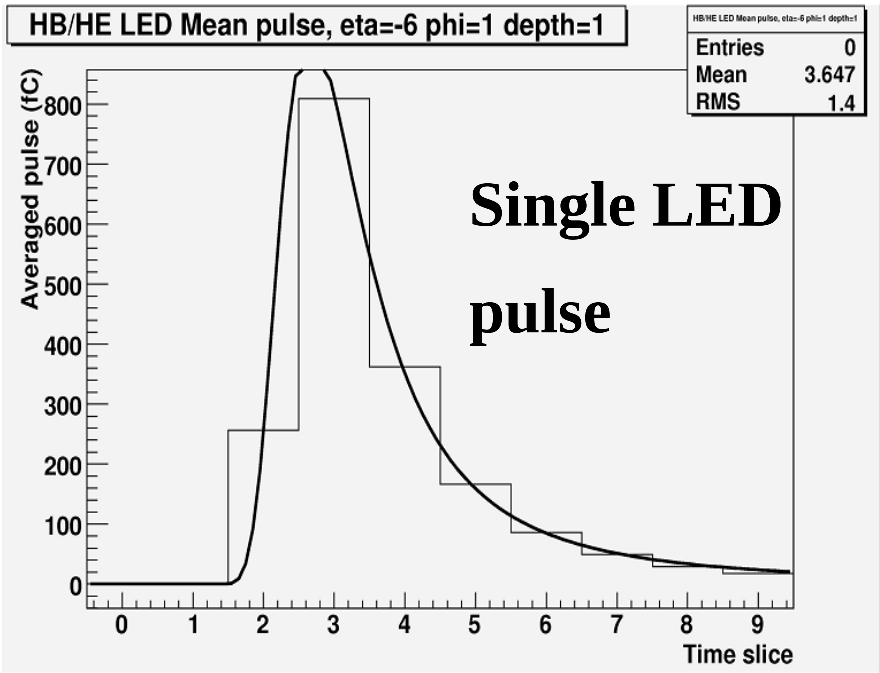


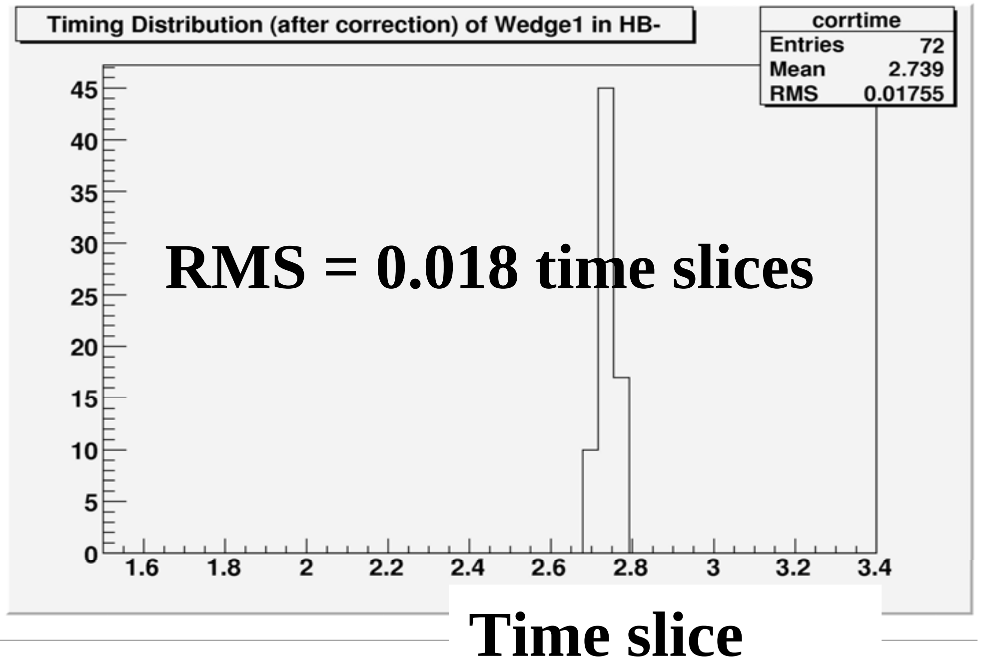


- **Typical Led Pulse**
- **Typical Laser Pulse**

- **Example from HB-LED data**
- **Analysis already has the required resolution**







3rd Input to Calibration: Basic Tower-by-Tower InterCalibration

- **Relative Energy Scale (already discussed – source + corrections):**
  - **Versus η ➔ Dominated by attenuation**
  - **Versus ϕ ➔ Dominated by gain of photo-detectors**
- **Absolute Energy scale**

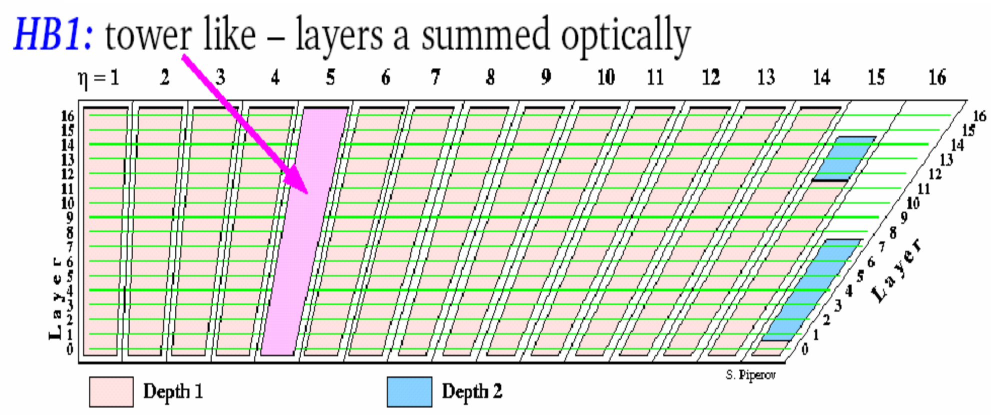
➔1st set of numbers from in-situ source data & testbeam (characterize source & longitudinal profile)

➔ *1.2 - 1.7 fC/GeV* (4% measurements)

➔2nd from Min. Bias & Isolated tracks

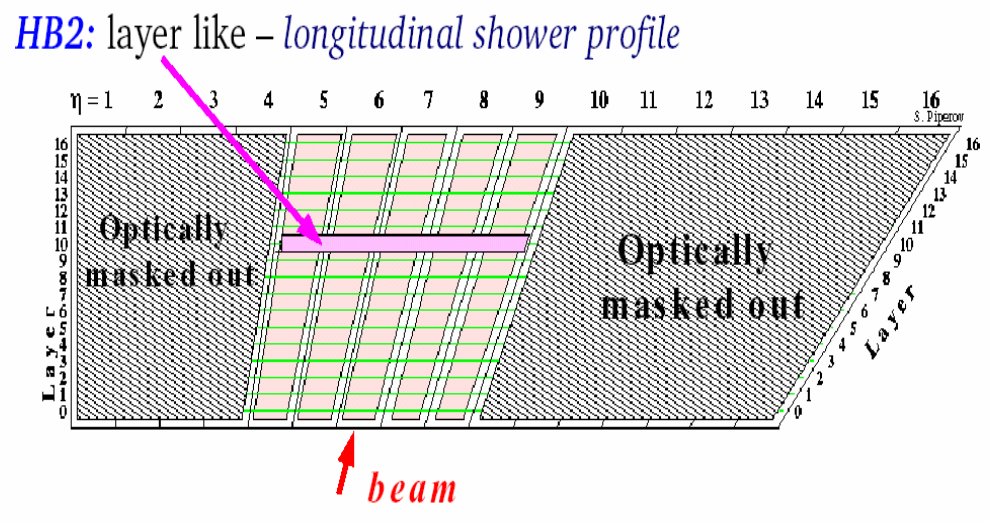
➔First set of collision data

Test beam allow to understand detector response and shower development for e-, π, μ
(J. Damagov)



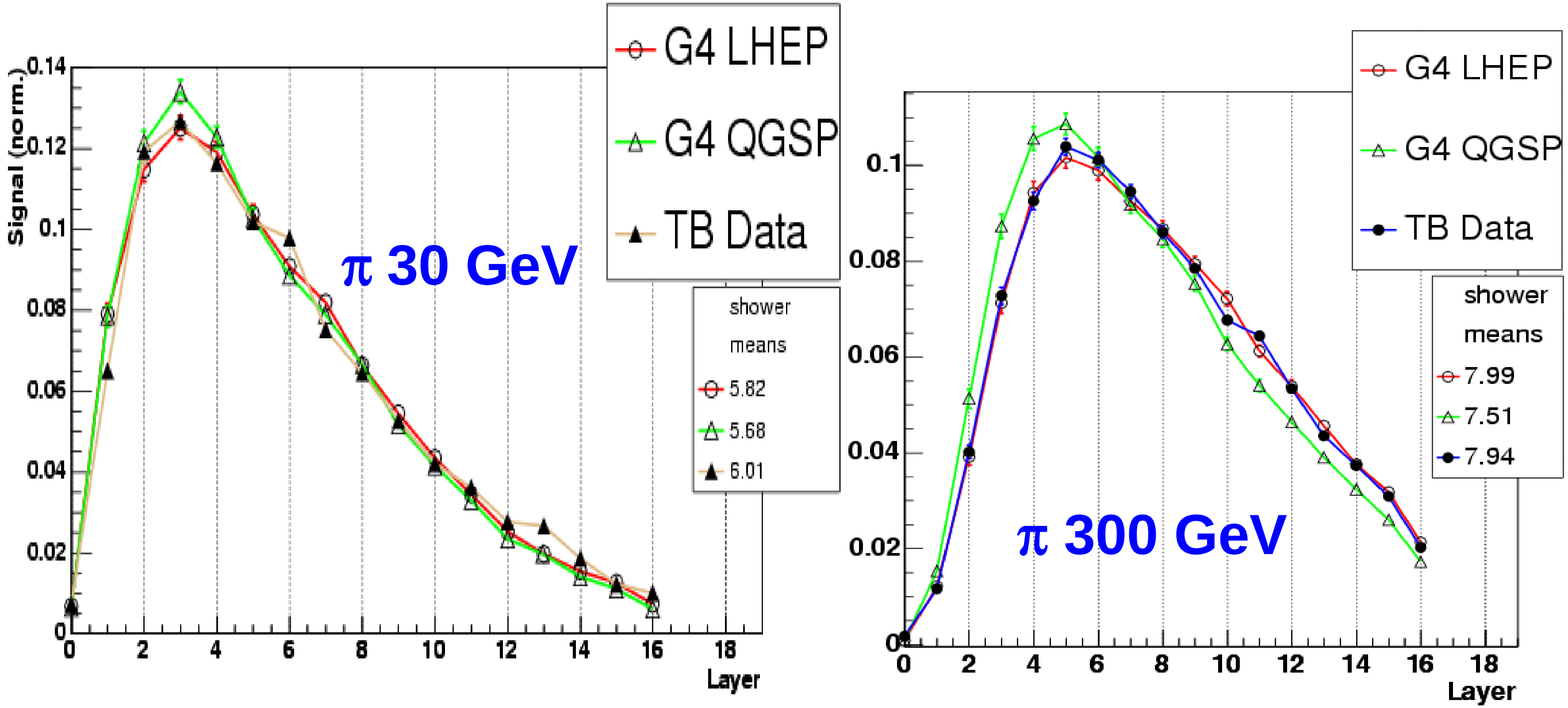
Initial Calibration Given for the Expected Mean Energy:

- **50 GeV π's for $\theta < 30^o$**
- **100 GeV π's for $\theta > 30^o$**



➔ Longitudinal shower profile needed.
➔ Source for each tile separately – (η , ϕ & layer)

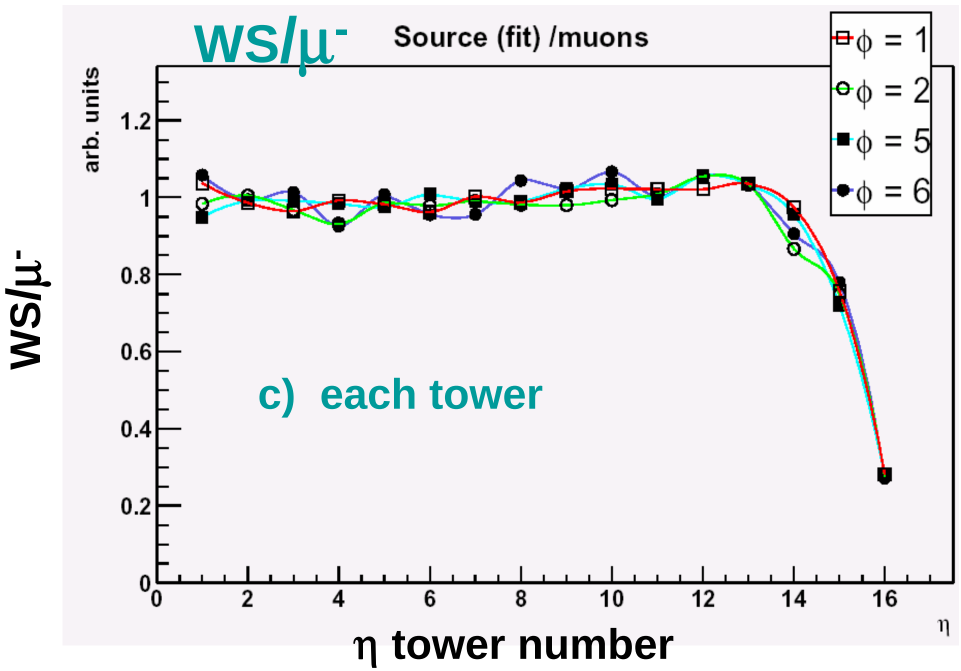
Longitudinal Shower Profile for π in HB



- **Therefore, ADC to GeV is not just one constant because it depends on the number of layers being illuminated & that makes it energy dependent.**

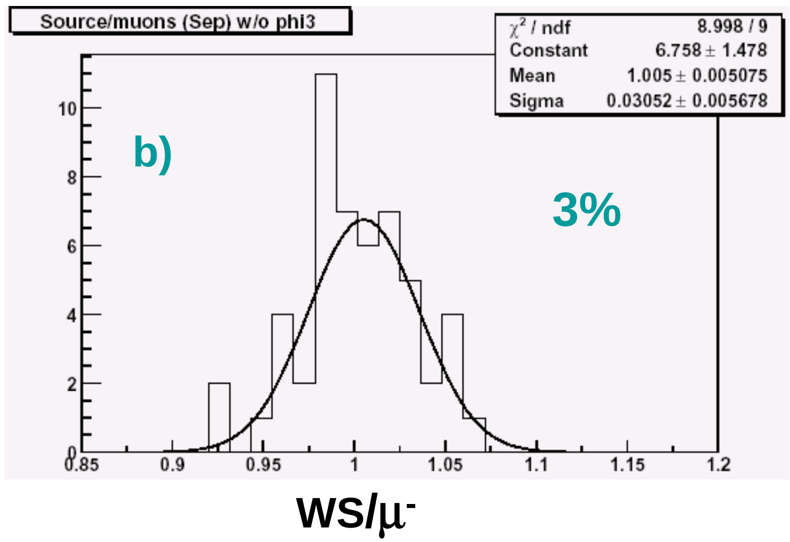
- **Muons "see" all planes**

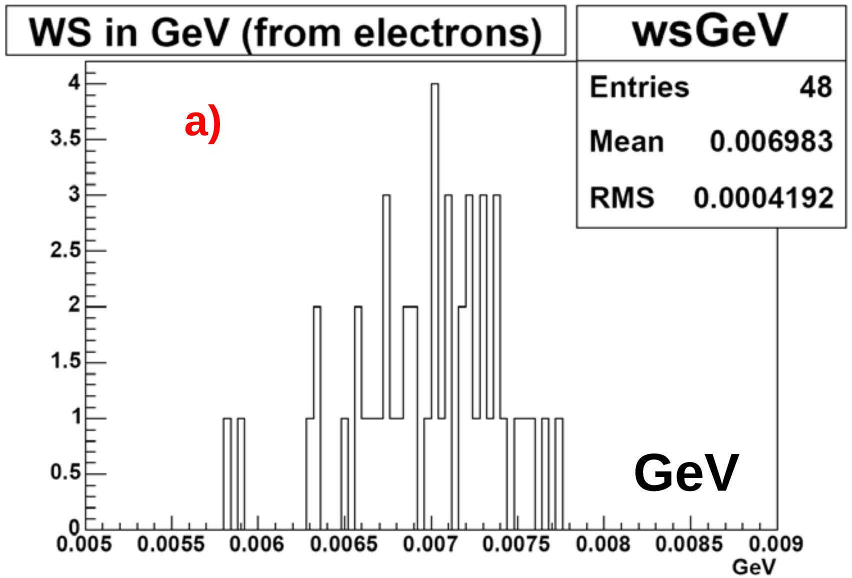
The "Energy" Calibration for the source is found during Testbeam by comparing source response to 100 GeV e-



a) Calibration of source with 100GeV electron beam.
→ 6.98 MeV equivalent
date == 2005-01-31

b,c) Compariosn with muon beam





Day "1" of collisions: Channels for initial calibration, monitoring & recalibration ➔ Calibration challenge in preparation

- **Min bias events: monitoring of energy in HCAL in full range ($|\eta|<5$) & provide uniformity in ϕ. ➔ 2% with a few hours @ $L=2x10^{33}cm^{-2}s^{-1}$**

- **Isolated particles: monitoring & calibration of energy in HCAL in the range of the Tracker acceptance ($|\eta|<2.4$) & for jet energy correction. ➔ 2% with a few days @ $L=2x10^{33}cm^{-2}s^{-1}$**

- **γ+jet events: monitoring of HCAL full range ($|\eta|<5$) & for jet energy correction.**

- **QCD dijet events: monitoring & calibration of energy in HCAL in the range outside the Tracker acceptance ($2.4<|\eta|<5$) & for jet energy corrections relative to particle jets.**

- **W➔jj from ttbar: monitoring, validation of jet energy correction**

Assumptions on - Run Type - Run Time – for calibration once collisions begin

- Physics
  - Beam
- Monitoring
  - LED
  - LASER 1&2
  - Pedestals
  - Sourcing
- Calibration
  - Pedestals
  - Beam
  - Sourcing
- Other
  - Test beam
  - Magnet test
  - Cosmic muons

- Running Time assumptions:

Filling	*Collisions*	*Filling*
> 2h	*< 15h*	*> 2h*

--------------- Discoveries ---------------

➔ ***These time scales give us an idea of the amount of processing time available & time between dedicated test of Hardware***

➔ ***Sourcing:***

**** full system once / year***

**** Layer 9 once / month***

Conclusions

- On "Day 1" we expect to already have:
  - Energy scale for every channel (η,ϕ) 3-5% error
    - Including corrections due to magnetic field effects
  - ADC to fC conversion factors available and know to better than 0.5%
  - Pedestal noise correlation understood and taken into account in reconstructions and simulation
  - Time synchronization to better than 2.5ns or 1/10 of bucket will be achieved

- Energy Scale constants to be superseded relatively quickly and a 2% change in any channel can be observed with 1-2hours